

# **Report for 2003MA19G: A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management**

There are no reported publications resulting from this project.

Report Follows

**Title:** A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management

**Start Date:** 9/30/2004 (No cost extension granted September 2004)

**End Date:** 9/29/2007

**Research Category:** Groundwater Flow

**Focus Category:** Water supply, Groundwater, Water Quantity

**Descriptors:** fracture characterization, domain analysis, well yield, fractured rock aquifers, groundwater availability, groundwater mapping, borehole geophysics

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## **Project Description**

### **Problem Statement**

The use of fractured-bedrock aquifers to meet private, public and commercial water supply needs is increasing in the New England region. Municipalities and water suppliers are finding it increasingly difficult to locate and develop water supplies in overburden aquifers because of contamination and a lack of suitable sites. In addition, recent droughts in the northeast have forced many communities and homeowners to drill new wells. As a result, water suppliers are going deeper into bedrock aquifers. Yet information on the factors that influence the availability and recharge characteristics of fractured bedrock aquifers in highly deformed crystalline metamorphic rocks is limited.

The availability of water in fractured rock aquifers is particularly critical in New England because growth and development along the coast, major transportation corridors and in rural communities adjacent to large metropolitan areas is rampant. For example, the I-495 corridor in Massachusetts, a circumferential highway 30 miles west of Boston, has become the focus of recent growth. Professional office buildings, research and development parks associated with the

computer industry, warehouses and light industry are springing up along this corridor, as are housing and condominium developments. Municipalities and water suppliers are simply unprepared for the onslaught of development and need help in understanding the complex dynamics of the ground water system.

Sustaining and managing ground water resources in fractured bedrock requires an evaluation of 1) the availability of water, 2) the source and vulnerability of recharge to water supply wells and 3) the impact of water withdrawals from the bedrock on streams, wetlands and unconsolidated aquifer systems that overlie the bedrock. These evaluations all require basic information on the physical characteristics of the ground water system.

## **Objectives**

The objectives of this project are to gather regional bedrock characteristics that relate to the occurrence and movement of ground water in bedrock and use this information to begin constructing regional conceptual models of the fractured-rock aquifers in the Nashoba terrane in Massachusetts. The approach utilizes existing information augmented by the collection of low-cost field data to develop regional conceptual models of the ground water flow system. Water managers can then use these conceptual models as an initial framework for formulating an understanding of bedrock flow behavior and recharge characteristics.

Specific tasks of this project involve: 1) Fracture Characterization and Domain Analysis - collection and synthesis of fracture characterization data over the region and mapping of the spatial distribution (domain analysis) of fracture sets and their characteristics, 2) Compilation and Analysis of Existing Well Data - compilation and statistical analysis, including variography, of available well data to link spatial continuity of well yields to characteristics of the fractured rock system, 3) Borehole Geophysics - collection of optical and acoustic televiwer data from selected boreholes to verify sheeting joints, 4) Compilation of Regional Litho-Group Map - development of a mapping classification system that uses the notion of "litho groups" to characterize bedrock units in terms of their fracture characteristics, physical properties and geologic setting (eg., overburden type and thickness) and 5) Conceptual Model - preparation of a qualitative conceptual model of ground water flow behavior in each litho group category.

## **Relationship of Project to USGS and Other Activities**

This project is part of a much larger, more comprehensive study being conducted by the USGS WRD Northborough office on the Geohydrology of the Nashoba Terrain, Massachusetts. This larger scale project involves the collection of data at three scales: regional, quadrangle and the local well-field scale. Recent work by the USGS in Connecticut and New Hampshire indicates that an understanding of ground water occurrence and movement in fractured rock aquifers can be made by combining the results of 1) fracture, geologic, well, and geophysical analyses performed at the regional level, 2) detailed mapping of bedrock lithology and physical characteristics that affect water occurrence and flow at the quadrangle scale, and 3) hydrogeologic and geophysical investigations at the well-field scale. This larger scale project is a joint effort that involves the participation of USGS scientists from the Water Resources Discipline, USGS mappers from the BRASS (Bedrock Regional Aquifer Systematics Study)

program, the Office of the Massachusetts State Geologist, and University of Massachusetts scientists (this project). Table 1 describes the tasks that each agency will perform and shows how the work will be coordinated.

Table 1. Coordination Plan and Approximate Timetable

<u>Task</u>	<u>Activity</u>	<u>Timetable</u>	<u>Responsible Party</u>
Existing Data (Regional Scale)	Base map	2003	USGS <sup>1</sup>
	Geologic map	2003	USGS
	Imagery	2003	USGS
	Fracture data/analysis	underway	This Project <sup>2</sup>
	Existing well data/analysis	underway	This Project
	Add'l well data in field	2005	USGS
	Borehole fracture data	2005	This Project/USGS
	Litho-group map	2006	This Project
Geologic & Fracture Data (Quadrangle Scale)	Map Quad #1-Grafton	Near completion	USGS BRASS <sup>3</sup>
	Map Quad #2-Marlboro	completed	State Geologist <sup>4</sup>
	Map Quad #3-to be deter.	2005	USGS BRASS <sup>3</sup>
	Map Quad #4-Hudson	completed	State Geologist <sup>4</sup>
Conceptual Model Devel.		2006	This Project/USGS
Test and Verify Model (Well Field Scale)		2006	USGS
Prepare and Publish Reports		2006/2007	This Project/USGS

<sup>1</sup> Start date of USGS cooperative project is March 2003, Bruce Hansen, USGS

<sup>2</sup> Start date of this project is September 30, 2004 (no cost extension granted)

<sup>3</sup> USGS BRASS = Bedrock Regional Aquifer Systematics Study project, Greg Walsh, USGS, began mapping in summer 2004; selection of a second quadrangle will be made spring 2005 and mapping commences in summer 2005

<sup>4</sup> State Geologist – Mapping funded by the STATEMAP component of the National Cooperative Geologic Mapping Program, Marlboro completed in June 2004, Hudson preliminary map completed in June 2005, Ayer quadrangle underway in summer 2005.

### **Work Accomplished on *This Project* to Date**

Alex Manda began working on this project in September 2004. Alex received his undergraduate degree in geology from Cardiff University in 2001 and finished his M.S. degree at Florida International University in August 2004. He passed his Ph.D. comprehensive exams at the University of Massachusetts in February 2005.

Work completed during the period September 1, 2004 and February 28, 2005.

1. Acquired Ground Water Site Inventory (GWSI) and pumping test data from the USGS (Task 2).
2. Assembled and analyzed well database using Geographic Information Systems (Task 2)\*.
3. Created Nashoba Terrane base maps in preparation for field mapping in Summer 2005.

4. Delineated areas in mapping region from which to collect fracture characterization and rock characteristics data.
5. Currently investigating spatial continuity of water well yields from the bedrock aquifer using geostatistics (Task 2).

On June 1, 2005 will commence field mapping and fracture characterization data collection with field assistant Steve Hubbs (Task 1). Training sessions for fracture data collection are underway. Will continue to investigate spatial continuity of well yield in the Nashoba terrane and will plan a work session with Larry Drew (USGS) to evaluate variography and geostatistical data analyses. Plan to participate in the Massachusetts Water Resources Research Conference in October 2005 to present preliminary results.

### **\*Summary of Preliminary Results of Well Inventory Analysis**

The GWSI data set provided 586 bedrock wells with well yield information collected from the ~ 600 square mile Nashoba Terrane. The data set is still, however, incomplete as other attributes such as drawdown, specific capacity and duration of pumping tests were either recorded for only a few wells or were not recorded at all. The GWSI data set will be augmented with other well data collected as part of quadrangle-scale mapping by the State Geologist in the Hudson, Marlborough and Ayer quadrangles.

The following attributes were investigated to verify how they affected well yield: Formation, overburden type, overburden thickness, topography, water use, construction method and depth of penetration of wells into bedrock.

The most productive formation was the Tadmuck Brook Schist with a median well yield of 0.08 gpm/ft. The least productive formation was the Marlboro with a median yield of 0.04 gpm/ft.

Overburden type does not appear to affect well yield although overburden thickness does. Wells that are located in areas that have an overburden thickness of between 10 and 100 feet provide the highest median yields. The highest median yield (0.09gpm/ft) is observed in wells that have an overburden thickness of between 30 and 50 feet.

Wells in upland draws, flats and terraces are the highest yielding wells with median yields of 0.11, 0.11 and 0.08 gpm/ft respectively. The majority of wells in the data set were located on hillsides, and these had the lowest median yield of 0.05 gpm/ft.

Wells constructed for provision of water to industrial and institutional facilities were the highest yielding wells with median yields of 0.14 and 0.10 gpm/ft. However, most of the wells in the database were constructed for domestic purposes and, as such, the domestic wells generally have lower yields.

There were predominantly three methods used to construct the wells in the Nashoba Terrane: Cable tool, Air Percussion and Air Rotary. Of these, cable tool and air percussion construction methods produced the highest median yield of 0.07gpm/ft.

High yields are observed where wells are drilled into bedrock between depths of penetration of 10 and 100 feet. Wells that penetrate bedrock between 10 and 30 feet give a median yield of 0.09 gpm/ft. As the depth of penetration increases to 30 – 50 feet the median yield increases to 0.13 gpm/ft.

### **Work Accomplished by Collaborators (Table 1)**

**USGS** – The USGS WRD Northborough office has acquired some funds to continue on this project. A meeting will be held this spring to determine data needs for the project.

**Office of the Massachusetts State Geologist** – The office of the Massachusetts State Geologist has contributed in the following way using funds supplied by the National Cooperative Geologic Mapping STATEMAP program.

1. A preliminary bedrock geologic map and a fracture characterization map have been prepared for the Hudson quadrangle. These maps provide detailed lithologic and fracture characterization data as well as information on the distribution of permeable overburden deposits at the quadrangle scale. These data will be used as a test for the regional scale litho-group maps to be prepared under this project.
2. A well database consisting of over 1400 wells has been assembled for the Hudson quadrangle. This includes six towns all located within the project area. These data will be used as part of the well inventory for the project.
3. During the summer of 2005, bedrock and fracture characterization data will be collected for the Ayer quadrangle. A well database is also being prepared for the towns located in this quadrangle.

**USGS BRASS Program** – Greg Walsh from the USGS BRASS program is completing bedrock and fracture mapping in the Grafton quadrangle. This will provide detailed lithologic and fracture characterization data for a third quadrangle within the project area. The State Geologist and BRASS are currently in the process of selecting a second quadrangle that will support this project. Mapping for this second project should begin in summer 2005.

### **Summary**

Alex Manda, who will perform the majority of the regional-scale work for this project, has begun work in earnest. Initial well data has been collected and general statistics performed on the data. Existing well-field pumping test and borehole geophysical data have been acquired from the USGS. Fracture data collection will commence in summer 2005. Collection of additional well-field scale pumping test data, borehole geophysical data, well inventory information and quadrangle-scale geologic and fracture mapping being performed by project collaborators is well underway and will continue through 2005.